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BORIS: a free, versatile open-source event-logging software for video/audio coding and live observations

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Summary

1. Quantitative aspects of the study of animal and human behavior are increasingly relevant to test hypotheses and find empirical support for them. At the same time, photo and video cameras can store a large number of video recordings and are often used to monitor the subjects remotely. Researchers frequently face the need to code considerable quantities of video recordings with relatively flexible software, often constrained by species-specific options or exact settings.

2. BORIS is a free, open-source and multi-platform standalone program that allows a user-specific coding environment to be set for a computer-based review of previously recorded videos or live observations. Being open to user-specific settings, the program allows a project-based ethogram to be defined that can then be shared with collaborators, or can be imported or modified.

3. Projects created in BORIS can include a list of observations, and each observation may include one or two videos (e.g., simultaneous screening of visual stimuli and the subject being tested; recordings from different sides of an aquarium). Once the user has set an ethogram, including state or point events or both, coding can be performed using previously assigned keys on the computer keyboard. BORIS allows definition of an unlimited number of events (states/point events) and subjects.

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4. Once the coding process is completed, the program can extract a time budget for single or grouped observations automatically, and present an at-a-glance summary of the main behavioral features. The observation data and time budget analysis can be exported in many common formats (TSV, CSV, ODF, XLS, SQL, JSON). The observed events can be plotted and exported in various graphic formats (SVG, PNG, JPG, TIFF, EPS, PDF).

Key-words: ethology, behavioral analysis, time-budget

Introduction

The methods used in behavioral sciences have changed dramatically in recent years due to the increasing availability of quantitative data. Researchers interested in collecting behavioral data to investigate the decision processes and communication strategies in humans and animals have taken advantage of new tools and approaches (e.g., Shteynberg et al. 2014; Baker 2011; Knoppien et al. 2000). The use of photos, video cameras and audio recorders that can store a large amount of data is now widespread in fields like psychology, primatology, entomology, anthropology, ornithology, medicine, neuroscience, and cognitive science (e.g., Cristani et al. 2013; Leong et al. 2003). There is also an increasing use of remote monitoring where researchers collect an impressive amount of data, which they have then to review to extract the target events (van Dam et al. 2013; Li et al. 2015). Computer-aided programs are thus instrumental in ensuring a manageable process that can lead to results (Visser 1993; Noldus et al. 2000).

Observational approaches to studying human and animal behavior lead to the commercial availability of various software that gradually developed into massively complicated applications, applicable to a multitude of particular systems and solutions (Spink et al. 2001; van Dam et al. 2013). The increasing complexity of these programs led to their development into relatively expensive suites of software. They satisfy the requirement of very specific research but may be inaccessible to other researchers, in particular to those working in institutions with an interest in behavior or those that are not affiliated with universities. Traditionally, commercial software also had limitations regarding the computers suitable to run the programs and were useable on a limited number of operating systems (e.g.; Observer XT, Noldus 2015; INTERACT, Mangold 2015), while usually offering a powerful set of analytical features (Spitzen et al. 2013; Adamson et al. 2013).

The answer to the increasing difficulty in accessing commercial software for observational research lead to the rise of free tools for the quantitative analysis of behavior (e.g.; JWatcher, Blumstein & Daniel 2007). They were usually simpler in terms of functions available and analysis routines. Most importantly, they lost the feature of a time-constrained integration between video playing and user coding (Blumstein & Daniel 2007).

BORIS integrates a highly customizable and flexible interface with time-constrained event logging that can be managed by pressing the keys on the keyboard. It can be used for various types of sampling (e.g., focal and scan sampling, Altmann 1974), and several subjects can be observed within the same project. The program allows the calculation of time budgets and provides statistics for the duration, occurrence and intervals of the events.

BORIS (Behavioral Observation Research Interactive Software)

BORIS is available for Microsoft-Windows, Mac OS X, and GNU/Linux platforms at http://www.boris.unito.it. The Python3 source code is released under the GNU General Public License at https://github.com/olivierfriard/BORIS.

Reviewing and coding visual and audio information in BORIS is easy and intuitive because of the integrated playback in which the time offsets of media files are recorded. Playing a variety of audio and video formats is a critical issue in any media-based program. BORIS is based on the popular VLC multimedia player libraries, which is a free and open source cross-platform framework.

A BORIS project file is a container for all information related to a set of observations, such as the ethogram, the independent variables, and the subjects. BORIS allows an unlimited number of projects, but only one project can be opened at a time. The time format can be set to either seconds or hours.

Defining the ethogram is the first essential step before starting logging behavioral events. This process is completely customizable and is when events are associated with keys. Alternatively, the user can set the ethogram from scratch; import an existing ethogram from another BORIS project; or import an ethogram from a JWatcher project (Blumstein & Daniel 2007). The behavior type can be defined as a 'Point event' or 'State event'. To enable more complex coding (e.g., facial expression coding; spatial position in a grid) the user can also add a 'Coding map' to either a state or a point event. Each behavior can be associated with a keyboard key that will then be used to log the behavioral events. The same key can be associated with more behaviors. In this latter case, BORIS will pause and ask which of the behaviors associated with that key the user wants to record. The keys are case-insensitive. A description of each behavior can be added and can be useful to standardize observations between different users. For each behavior, a series of modifiers can be added.

The modifiers can be used to add attributes to behaviors. A single behavior can have two or more modifiers attached (e.g., "play" may have "solitary" or "social" as modifiers). The use of modifiers can be convenient to significantly reduce the number of keys and simplify the behavioral coding. In BORIS, modifiers can also be added in different sets [e.g., "play, social" may have a modifier set (#1) for "brothers" and another (#2) for "sisters"]. Mutually exclusive states can be set in an exclusion matrix so that the beginning of an event will correspond with the end of another. We worked to ensure that users can freely organize the behavioral codes and decide whether they want to use modifiers or assign more codes to the same key.

The user interface has a toolbar, which, along with the other modules, can be undocked. It features popular video controls for play, pause, stop, fast-forward/backward. BORIS can be switched on and off to a frame-by-frame mode during observations and slowed down to a desired percentage of the original tempo. This feature makes it possible to analyze each step in the video easily, with more detail and focus on a particular display (e.g., muscle contractions, subtle gestures). With a click, the user can capture still frames.

The accuracy of the video coding can be improved by repeated views of a media if needed. Once moving across the media, each key pressed results in the insertion of a behavioral display at the time in which it occurs in the video. The occurrence of a behavior in an individual can be reviewed using a graphical representation or by generating a time budget analysis. Collected data can be exported in many formats (e.g. TSV, CSV, ODF, XLS, SQL, JSON) to allow further analysis.

In recent years, remote video camera traps have been used for population assessment and for capturing behavioral traits of elusive species (Tan et al. 2013). They are a valuable monitoring tool and enable long-term spatiotemporal monitoring, which usually results in a series of short videos of fixed duration (from the triggering of motion detectors to a programed delay time). Once the video footage is downloaded from the camera traps onto a computer, the behavioral biologist faces the challenge of coding this long series of very short videos. Within a single observation, BORIS has a particular function for this task, which allows the automatic loading of all videos from a selected directory and the interrupting all the current states when passing from one video footage to another. This feature enables a more convenient identification of the actual observation time of the target individuals and an easier switching between individuals that may occur in one video but not in the following one.

While screening the video, the program also allows the visualization of a sound spectrogram of the associated audio information. A spectrogram (or sonogram) is the visual representation of a sound that shows frequencies (on the vertical axis) with variation in time (on the horizontal axis, Fig. 4). The degrees of amplitude are represented as color gradients. A spectrogram facilitates the recognition of common acoustic structures and can be crucial in associating a particular behavior with concurring vocalizations. The program also features an analytical measurement tool that allows measuring angles, distances, and areas from the video (Supporting information S7).

Example of use

To showcase the main functions of BORIS we present behavioral coding performed by Dr. Valentina Matteucci on the video recordings of a captive colony of ring-tailed lemurs (*Lemur catta*) at the ZOOM Torino zoological park (www.zoomtorino.it), Cumiana, Italy. Recordings were made with a commercial camcorder Panasonic HC-V720. Dr. Matteucci, in collaboration with OF and MG, compiled the complete ethogram of the ring-tailed lemur from previous research (Jolly 1966; Evans & Goy 1968; Pereira et al. 1988; Macedonia 1993; Oda 1996; Pereira & Kappeler 1997; Wilson 2002; Mertl-Millhollen 2006; Palagi & Norscia 2009; Palagi 2009; Sclafani et al. 2012). Additional behaviors were added after observations by Matteucci and Baracco (unpublished data). The resulting BORIS file containing the full behavioral repertoire of the ring-tailed lemur is available at http://www.boris.unito.it/files. It comprises 104 behaviors (Supporting information S4).

As an example of use, we selected six subjects for the observations using their in-house names (Ciro, Totò, Maurice, Fossar, Giulian, Seven). Dr. Matteucci coded three videos in BORIS at half speed and scored the results indicating the occurring behaviors and subjects (Supporting information S5). To simplify the visualization of the analyses we show here, the behavioral repertoire in these videos has been reduced considerably, from 104 to 26 behaviors. In Fig. 1 we show the composite view of the Ethogram, Subjects, Video and Events tabs for the observation DEMO1. To visualize the occurrence of each behavior and the individual time budget we used the Time Budget function in BORIS ('Analyze'>'Time Budget'; Fig. 2). The Time budget can be calculated from several observations by selecting them from the Observation List (e.g., recordings on the same day). In this example, we analysed three different observations together (observations DEMO1, DEMO2, and DEMO3 corresponding to videos in Supporting information S1, S2, and S3, respectively). For each subject, we visualized the occurrence of behaviors and the duration of each state ('Analyze'>'Plot events'; Fig. 3).

Conclusion and future directions

BORIS offers a customizable and intuitive interface for behavioral observations, implementing novel ideas and widely used functionalities (Supporting information S6). The user fully controls the lists of behaviors and subjects. These lists can be exchanged between projects, modified and shared with colleagues. Coding of the audio and video files can be performed at various speeds, but also switched to a 'frame by frame' video analysis. Event recordings are activated by pressing a key when the corresponding behavior occurs.

We have made improvements on earlier versions to make it easier for users to code multiple video files within the same project. The result is better management of the 'Observations List' with regard to both setting the project and in the calculation of the time budget and the data visualization.

We are currently working on the integration of web services (e.g., sequential analysis), which will be able to receive information from a BORIS project.

The features of this program fit well with the current academic and institutional scenario, where a profound scientific understanding of data must be achieved with flexible and affordable tools.

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Data accessibility

Videos and BORIS project files used for testing are available in the supplemental documents. A features comparison table across popular observational data software is available as supporting information.

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Supporting Information

The files used in the examples are available from http://www.boris.unito.it/files.

Supporting information S1. Video recording of a captive colony of ring-tailed lemurs (*Lemur catta*) at ZOOM Torino.

Supporting information S2. Video recording of a captive colony of ring-tailed lemurs (*Lemur catta*) at ZOOM Torino.

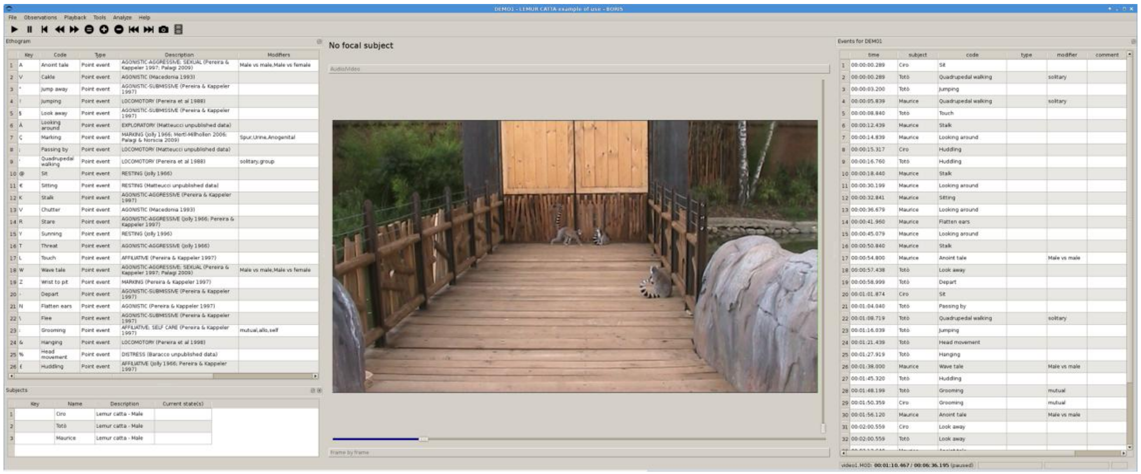
Supporting information S3. Video recording of a captive colony of ring-tailed lemurs (*Lemur catta*) at ZOOM Torino.

Supporting information S4. *Lemur catta* ethogram. BORIS project files containing an ethogram with 104 codified behaviors.

Supporting information S5. Example of use. BORIS project files containing three observations, of video S1, S2, and S3, respectively.

Supporting information S6. Features comparison table across popular observational data software.

Supporting information S7. Example of use. Distance measurement.



Time budget

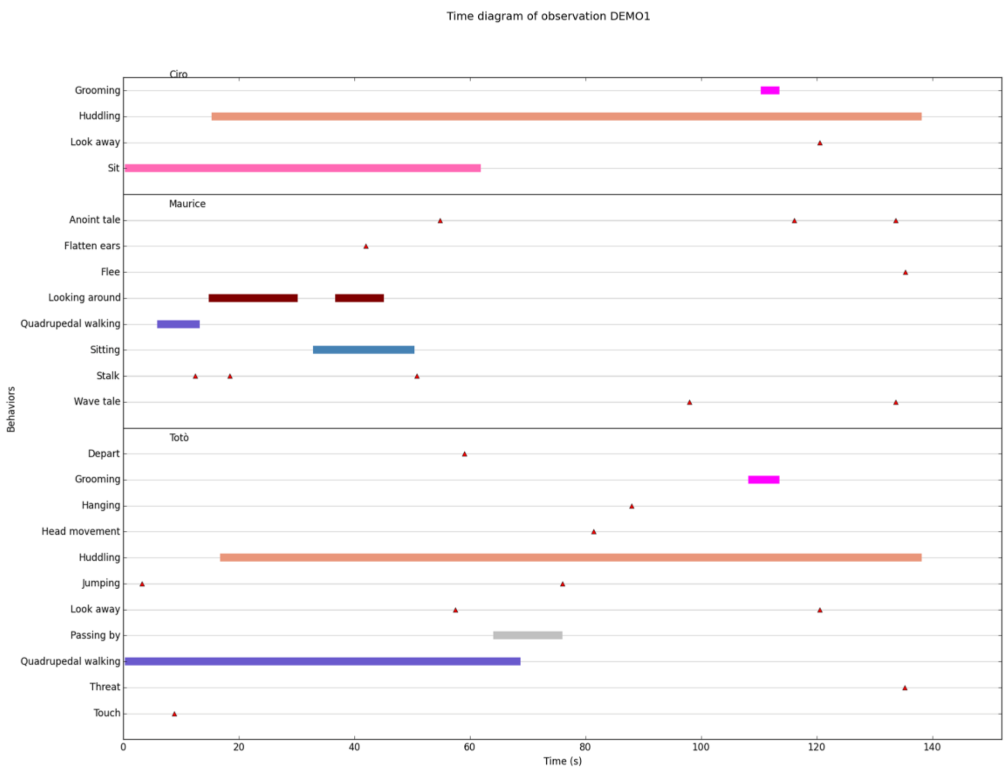
Selected observations

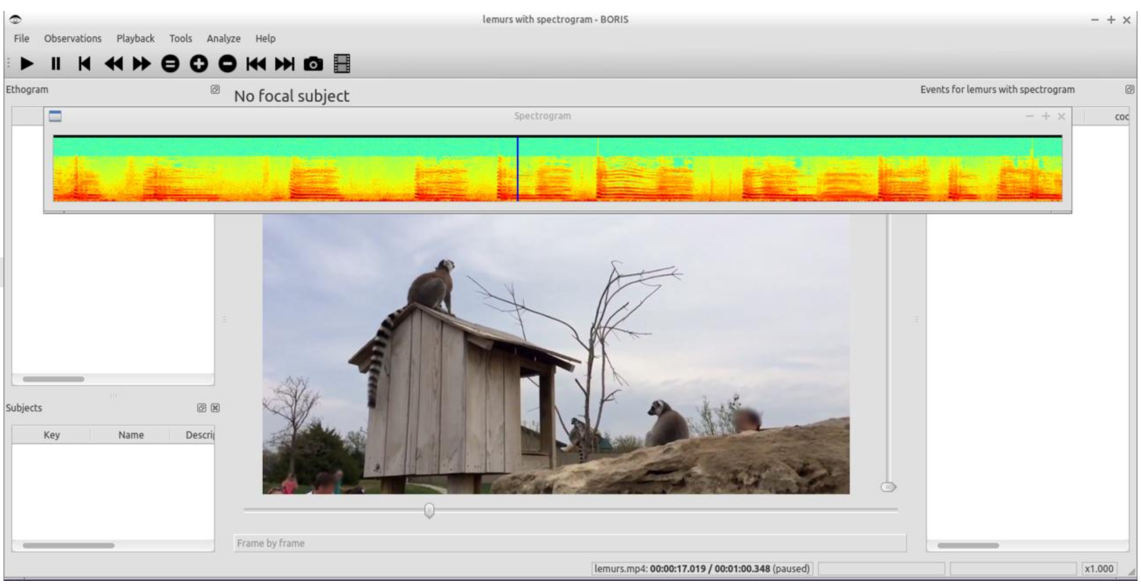
DEMO1

Total media length: 00:02:32.240

	Subject	Behavior	Modifiers	Total number	Total duration (s)	Duration mean (s)	Duration std dev	inter-event intervals mean (s)	inter-event intervals std dev	% of total media length
1	Ciro	Huddling	NA	2	77.041	38.521	8.657	45.841	NA	50.6
2	Ciro	Look away	NA	1	-	-	-	NA	NA	-
3	Maurice	Anoint tale	NA	3	-	-	-	39.42	30.971	-
4	Maurice	Flatten ears	NA	1	-	-	-	NA	NA	-
5	Maurice	Flee	NA	1	-	-	-	NA	NA	-
6	Maurice	Looking around	NA	2	7.321	3.661	1.445	29.4	NA	4.8
7	Maurice	Quadrupedal walking	NA	1	5.88	5.88	NA	NA	NA	3.9
8	Maurice	Sitting	NA	1	-	-	-	NA	NA	-
9	Maurice	Stalk	NA	2	-	-	-	32.4	NA	-
10	Maurice	Wave tale	NA	2	-	-	-	35.64	NA	-
11	Totò	Depart	NA	1	-	-	-	NA	NA	-
12	Totò	Hanging	NA	1	27.234	27.234	NA	NA	NA	17.9
13	Totò	Head movement	NA	2	-	-	-	6.96	NA	-
14	Totò	Huddling	NA	2	74.878	37.439	6.449	46.561	NA	49.2
15	Totò	Jumping	NA	2	-	-	-	72.839	NA	-
16	Totò	Look away	NA	2	-	-	-	63.121	NA	-
17	Totò	Passing by	NA	3	-	-	-	44.1	52.524	-
18	Totò	Quadrupedal walking	NA	UNPAIRED	UNPAIRED	UNPAIRED	UNPAIRED	UNPAIRED	UNPAIRED	-

Save results Close


Time diagram of observation DEMO1
Ciro
Grooming
Huddling
Look away
Sit
Maurice
Anoint tale
Flatten ears
Flee
Looking around
Quadrupedal walking
Sitting
Stalk
Wave tale
Totò
Depart
Grooming
Hanging
Head movement
Huddling
Jumping
Look away
Passing by
Quadrupedal walking
Threat
Touch
Behaviors
0
20
40
60
80
100
120
140
Time (s)


lemurs with spectrogram - BORIS
File
Observations
Playback
Tools
Analyze
Help
Ethogram
No focal subject
Events for lemurs with spectrogram
Spectrogram
Subjects
Key
Name
Frame by frame
lemurs.mp4: 00:00:17.019 / 00:01:00.348 (paused)
x1.000